The following supplement accompanies the article

Trade-offs between foraging efficiency and pup feeding rate of lactating northern fur seals in a declining population

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Table S1: Relative proportion (%), average prey mass (in g), prey energy density (ED in kJ/g), energy content (in kJ) of prey species in the diets of female northern fur seal breeding on St. Paul (representative of the neritic group), and of females breeding on Bogoslof Island (representative of the oceanic group) (Jeanniard du Dot et al. 2017). Split-sample frequency of occurrences of prey groups in diets (% SSFO) were obtained from morphological identification of hard part remains (Jeanniard du Dot et al. 2017) and from collection of samples of Bogoslof Island rookeries in 2009 (Trites et al. 2015). Mass was calculated from size of hard part remains.

	Prey group	Prey species	% in diet	Mass (g)	ED (kJ/g)	EC (kJ)
NERITIC NFS	Gadid	Pollock	62.75	16.48 ± 1.11	4.12 ± 0.33	67.87 ± 0.24
		Pacific cod	7	6.76 ± 1.14	2.94 ± 0.12	19.72 ± 0.11
	Caphalopod	Cephalopod	12.28	3.74 ± 0.29	4.76 ± 0.11	17.79 ± 0.04
	Salmon	Salmon	6.03	797.78 ± 53.65	5.53 ± 0.30	4425.00 ± 9.80
	Hexagrammid	Atka mackerel	2.92	18.69 ±2.37	4.02 ± 0.08	75.19 ± 0.29
		Kelp Greenling	0.72	NA	3.45	NA
	Mesopelagic	Northern smoothtongue	2.42	3.87 ± 0.25	5.67 ± 0.25	21.91 ± 0.05
	Forage	Sand lance	0.83	12.76 ± 0.05	5.06 ± 0.12	64.55 ± 0.05
		Sandfish	0.42	8.01 ± 1.04	3.55 ± 0.13	28.52 ± 0.12
		Capelin	0.28	8.49 ± 0.31	4.35 ± 0.35	36.95 ± 0.11
	Flatfish	Arrowtooth flounder	0.28	3.78 ± 0.01	5.14 ± 0.75	19.45 ± 0.08
	Other	Rockfish sp.	0.33	3.78 ± 0.06	2.97	NA
		Non-fish	2.5	NA	NA	NA
		Worm	1.25	NA	NA	NA
OCEANIC NFS	Gadid	Pollock	0.86	16.48 ± 11.45	4.12 ± 0.33	67.87 ± 0.24
	Caphalopod	Octopus sp.	42.70	3.74 ± 0.29	4.76 ± 0.11	17.79 ± 0.04
	Salmon	Salmon	3.87	797.78 ± 8.92	5.53 ± 0.30	4425.00 ± 9.80
	Hexagrammid	Atka mackerel	0.60	18.69 ± 2.37	4.02 ± 0.08	75.19 ± 0.29
	Mesopelagic	Northern lampfish	2.75	2.02 ± 1.01	8.98 ± 1.74	17.84 ± 0.30
		Northern smoothtongue	46.22	3.87 ± 0.25	5.67 ± 0.25	21.91 ± 0.05
	Forage	Pacific herring	0.52	23.49 ± 5.75	6.3 ± 0.22	147.76 ± 1.14
		Sand lance	1.03	12.76 ± 0.05	5.06 ± 0.12	64.55 ± 0.05
	Other	Sablefish	0.86	NA	NA	NA
		Polychaete unident.	0.34	NA	NA	NA
		Threespine stickleback	0.26	NA	NA	NA

Equations to estimate body length and mass of fish and squid

The following equations used to convert the lengths of otolith (OL) and squid beaks (LRL) into body length (FL) and mass (BM) for nine species consumed by northern fur seals:

- ***Walleye pollock***. $FL = 0.50\ OL^2 + 15.74\ OL + 13.3$ (Zeppelin et al. 2004)
  $BM = 0.0077 \times FL^{2.906}$ (Frost & Lowry 1981)
  Walleye pollock were separated into age classes using the cutting length of 100mm below which they were considered of age-0+ and above which they were of age-1+ (Whitman 2010, Honkalehto et al. 2012)

- ***Salmon.*** $BM = 0.0103 \times FL^{3.092}$ (Harvey et al. 2000)
  Simulations: 31.75 ± 0.14 cm and 797.78 ± 8.92 g (from 55% of fish between 16-24 cm, and 45% between 35–59cm)

- ***Atka mackerel***. $FL = 8.40\ OL - 4.99$ and $BM = 0.0034 \times FL^{3.401}$ (Harvey et al. 2000)

- ***Northern smoothtongue***. $BM = 0.0106 \times FL^{2.85}$ (Orlov & Binohlan 2009)

- ***Capelin***. $FL = 3.45\ OL + 3.62$ and $BM = 0.0054 \times FL^{3.160}$ (Harvey et al. 2000)

- ***Pacific herring***. $FL = 5.24\ OL - 1.85$ and $BM = 0.0044 \times FL^{3.398}$ (Harvey et al. 2000)

- ***Arrowtooth flounder***. $FL = 4.75\ OL - 2.96$ and $BM = 0.0093 \times FL^{2.999}$ (Harvey et al. 2000)
  Simulations: 6.00 ± 0.005 cm and 3.78 ± 0.006g (from 100% of fish between 5–7 cm)

- ***Pacific sand lance***. $FL = 4.06\ OL - 2.01$ and $BM = 0.0063 \times FL^{2.790}$ (Harvey et al. 2000)
  Simulations: 15.00 ± 0.02 cm and 12.76 ± 0.05g (from 100% fish between 11–19 cm)

- ***Squid***. Measures of lower beak rostrum length (LRL) were converted into squid mass using the equations $\ln(BM) = 2.52 + 1.99 \times \ln(LRL)$ (Clarke 1962)

Table S2: Standardized Regression coefficients (SRC), the min and max 95% confidence intervals, biases and standard errors (SE) of the sensitivity analysis of the calculated foraging efficiency of lactating northern fur seal females foraging on the shelf in neritic waters or off the shelf in oceanic waters from energy expenditure at sea (EE in MJ), prey capture attempts (PrCA), mass (g), energy density (ED in kJ/g) and relative proportion in the diet of different prey item (Prop.).

Group	Parameters	SRC	Min 95% CI	Max 95% CI	Bias	SE
Neritic	**EE**	-0.344	-0.352	-0.335	0.000	0.004
	PrCA	0.861	0.855	0.867	0.000	0.003
	Gadid Mass	0.001	-0.005	0.007	0.000	0.003
	Gadid ED	0.012	0.006	0.019	0.000	0.003
	Gadid Prop.	0.010	0.003	0.016	0.000	0.003
	Ceph. Mass	0.012	0.005	0.018	0.000	0.003
	Ceph. ED	0.005	-0.001	0.012	0.000	0.003
	Ceph. Prop.	0.007	0.000	0.013	0.000	0.003
	Salmon Mass	-0.003	-0.009	0.004	0.000	0.003
	Salmon ED	0.001	-0.005	0.007	0.000	0.003
	Salmon Prop.	-0.001	-0.007	0.006	0.000	0.003
	Hexag. Mass	0.000	-0.006	0.006	0.000	0.003
	Hexag. ED	0.002	-0.004	0.008	0.000	0.003
	Heaxg. Prop.	0.002	-0.005	0.008	0.000	0.003
	Forage Mass	0.001	-0.005	0.007	0.000	0.003
	Forage ED	0.005	-0.002	0.011	0.000	0.003
	Forage Prop.	0.000	-0.006	0.006	0.000	0.003
	Meso. Mass.	0.039	0.033	0.045	0.000	0.003
	Meso. ED	0.053	0.047	0.060	0.000	0.003
	Meso. Prop.	0.217	0.209	0.225	0.000	0.004
	Flat. Mass	-0.003	-0.009	0.003	0.000	0.003
	Flat. ED	-0.003	-0.010	0.003	0.000	0.003
	Flat. Prop.	-0.002	-0.008	0.004	0.000	0.003
Oceanic	**EE**	-0.752	-0.771	-0.732	0.000	0.010
	PrCA	0.621	0.606	0.636	0.000	0.008
	Gadid Mass	0.000	-0.011	0.010	0.000	0.005
	Gadid ED	0.012	0.001	0.022	0.000	0.005
	Gadid Prop.	0.004	-0.007	0.014	0.000	0.005
	Ceph. Mass	-0.001	-0.011	0.009	0.000	0.005
	Ceph. ED	0.004	-0.006	0.015	0.000	0.005
	Ceph. Prop.	0.004	-0.006	0.014	0.000	0.005
	Salmon Mass	0.005	-0.005	0.016	0.000	0.005
	Salmon ED	0.002	-0.008	0.012	0.000	0.005
	Salmon Prop.	0.004	-0.006	0.015	0.000	0.005
	Hexag. Mass	0.012	0.002	0.022	0.000	0.005
	Hexag. ED	-0.001	-0.011	0.009	0.000	0.005
	Heaxg. Prop.	0.008	-0.002	0.019	0.000	0.005
	Forage Mass	0.004	-0.005	0.014	0.000	0.005
	Forage ED	-0.003	-0.013	0.007	0.000	0.005
	Forage Prop.	0.004	-0.006	0.013	0.000	0.005
	Meso. Mass.	0.473	0.460	0.485	0.000	0.006
	Meso. ED	0.068	0.058	0.078	0.000	0.005
	Meso. Prop.	0.312	0.300	0.324	0.000	0.006

Milk samples analyses

Milk samples were collected while females were under anesthesia. We obtained milk in quantity sufficient for proximate composition analyses (> 3 ml) in only 10 of my 20 females (5 before their foraging trip and 5 after). After collection, milk samples were stored in the freezer at -20ºC until analyses. Proximate composition analyses were performed by SGS Canada Inc. Moisture, ash, protein and fat content of milk samples were measured using the AOAC 935.29, 942.05, 990.03, and 989.05 methods respectively. Energy density of milk samples were calculated using the Atwater method. Relationship between time at sea and milk fat content prior or after foraging trip and trip duration was estimated using simple linear regressions (*lm* in 'base' library, R 3.2.6).

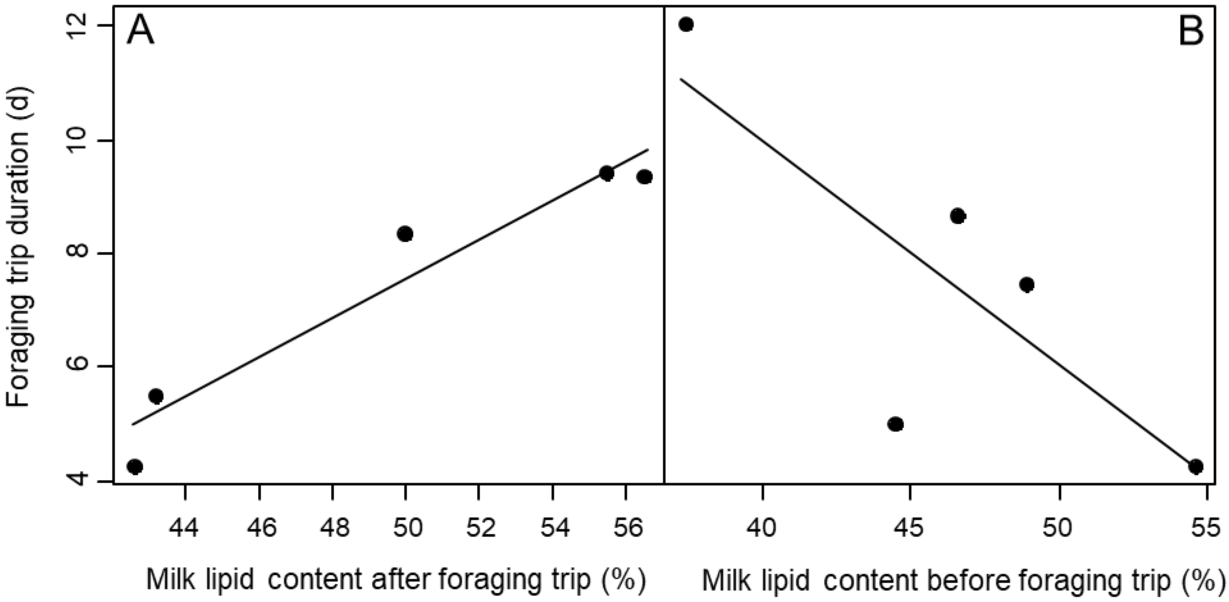

Fig S1: Foraging trip duration of females as a function of the milk lipid content after the trip (A, n = 5) or prior to it (B, n = 5). Regression lines between the 2 parameters are added on both graphs (A: slope $p = 0.007$, $R^2 = 0.93$, B: slope $p = 0.104$, $R^2 = 0.64$).

Pup growth

Respective pups of our tracked females were captured once the mothers left the rookery to forage, and standard morphometric measurements of length and girth were taken to the nearest 0.5 cm and ± 0.1 kg. Unfortunately, field conditions made it impossible to follow the growth of individual pups associated with each tracked mother over multiple weeks. We therefore performed cross sectional sampling by capturing 80 pups of both sexes selected at random, and took morphometric measurements 3 times over the course of the breeding season in 2011: between Aug 18–21, Sep 7–10, and Sep 20–21. We modeled pup mass data with a linear model for each sex individually, as well as for data from the 1980s on Bering Island (Boltnev et al. 1998), and from 1996 on St. Paul Island (Donohue et al. 2000). Differences in slopes between these models were estimated using a test for equality of regression coefficients (Paternoster et al. 1998). The significance of relationships between mass, mass changes, and foraging efficiencies of mothers, as well as the relationships between pup parameters and mother parameters were all estimated using linear regressions models (lm in '*stats*' package, R.3.3.0).

Ages of pups were approximated based on a median pupping date of July 6th (Trites 1992). Female pups weighed 7.93 ± 1.00 kg at age 42 - 45 days, 9.51 ± 1.82 kg at 62 - 65 d, and 10.24 ± 1.6 1kg at ages 75 - 76 d. In contrast, male pups were about 15% bigger, weighing 9.45 ± 1.53 kg at age 42 - 45 days, 10.88 ± 1.98 at 62 - 65 d, and 11.95 ± 1.79 kg at 75 - 76 d). These measures of pup body mass are consistent with pup mass recorded on Bering Island, Russia in the 1980s).

Linear models predicting body mass of pups as a function of age fitted to our 2011 data were:

BM (kg) = 0.07 × Age (d) + 4.76 for female pups

BM (kg) = 0.08 × Age (d) + 6.07 for male pups

Linear models fit to data from the 1980s (Boltnev et al. 1998) were:

BM (kg) = 0.07 × Age (d) + 5.03 for female pups

BM (kg) = 0.09 × Age (d) + 5.52 for male pups

Linear models fit to data from 1996 (Donohue et al. 2000) were:

BM (kg) = 0.08 × Age (d) + 4.67 for female pups

BM (kg) = 0.10 × Age (d) + 5.62 for male pups

Analyses of variances on the slopes of these models showed that pups in 2011 had a slower growth than pups in the 1980s or in 1996 (p < 10-5 in all cases).

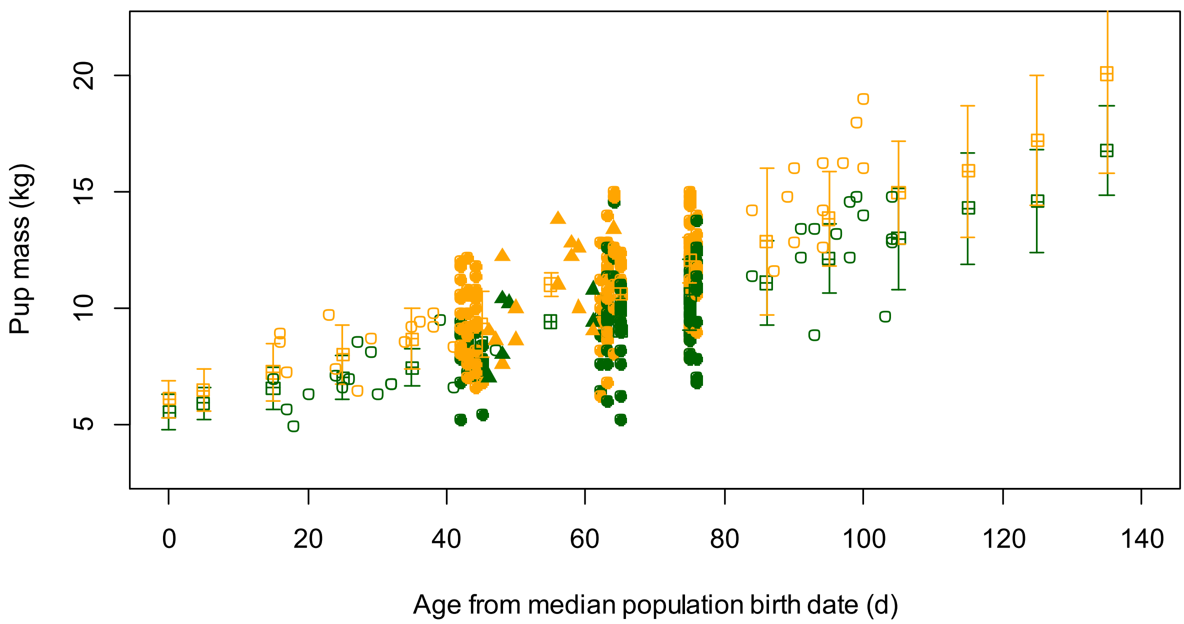

Figure S2: Mass of male (in orange) and female (in green) northern fur seal pups over the course of the nursing period, from age 0 to weaning (in days). Closed circles show data collected on random pups during the nursing season 2011 on St. Paul Island. Triangles show the mass of pup associated with the females tracked at sea during the same field season. Open circles show the mass-at-age data collected on St. Paul Island in 1996 (Donohue et al. 2000) and open squares show the mean mass ± SD of pups weighed on Bering Island, Russia in the 1980s from Boltnev et al. (1998).

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